ACOUSTIC EMISSION FROM CARBON FIBRE REINFORCED CARBON COMPOSITES

M J Fry, MOD (PE), AWRE, Aldermaston, Reading RG7 4PR, England

Introduction

When a material is stressed localised deformations result in the release of strain energy, generating stress waves which can be detected by a sensor coupled to the material surface. These stress waves, or acoustic emissions (AE) are characteristic of the failure process and their study will lead to a greater understanding of fracture mechanisms occurring in materials.

In fibre reinforced composites sources of acoustic emission are fibre fracture, matrix cracking and debonding at the fibre-matrix interface. The most energetic failure process is expected to be associated with fibre breakage, and several authors (1,2,3,4) working on fibre reinforced plastic report this mechanism as the major source of emission in these composites.

Experimental Methods

Unidirectional carbon-carbon composites were fabricated from a precursor which consisted of sheets of high strength, non surface treated carbon fibre tow preimpregnated with a phenolic novolak resin. Layers of this prepreg material were hot pressed followed by carbonisation in an argon atmosphere. The specimens were then densified by the deposition of pyrocarbon using either an isothermal or thermal gradient technique.

All specimens were tested by three point bending on an Instron Universal Testing Instrument. The acoustic emission signals were processed by an AECL 105 Acoustic Emission System using a system gain of 80dB and a 100-300 KHz band pass filter.

Results

Figure 1 compares typical acoustic emission responses with stress for the green, carbonised and densified composites. The relatively high number of counts for the densified and carbonised composites at low stresses compared with the response of the green material can be attributed to cracking in the carbon matrix. The strain to failure of the densified composites is of the order of 1% compared to a matrix strain to failure of approximately 0.3% and consequently matrix damage is a significant contribution to the acoustic emission monitored at 80dB.

Matrix failure is also a probable explanation of the different behaviour of the two densified materials. The isothermally densified composites generally have a higher weight increase on densification than the thermal gradient composites (15-20% compared with 10-12%) and the former usually have a pyrocarbon surface coating. This pyrocarbon surface deposit is observed to crack at low stresses and strains and this will contribute towards the higher number of counts in the isothermally densified composites. Differences in the fine structure of the deposited pyrocarbon for each of the densification processes may also be a factor leading to the variation in the acoustic emission responses of carbon-carbon composites.

An indication of the energy of an emission can be obtained by measuring the transducer signal on an RMS voltmeter, since the energy output is proportional to the square of the voltage at the transducer terminal. Many specimens exhibited high energy peaks at stresses well below the failure level and each peak was associated with an increased rate of emission. The higher the stress at which the first significant energy peak occurred the greater was the failure stress of the composite.

Figure 2 shows the acoustic emission obtained for a selection of carbon-carbon composites during cycling between 0 and 0.4 GPa. There is clearly a relationship between the ultimate flexural strength of a composite and the slope of the acoustic emission trace after the first load cycle. Figure 3 shows this relationship. Above a threshold fracture stress of approximately 1GPa the total number of counts during 15 cycles is independent of the ultimate strength and is of the order 10^4 or less. For composites having a fracture strength significantly less than 1GPa the number of counts is at least an order of magnitude higher.

Conclusions

Acoustic emission can distinguish carbon-carbon composites manufactured by different process routes and also the precursor materials. Low strength composites are characterised by the emission of high energy events at low stress levels. The results obtained during cycling of carbon-carbon composites suggests the use of AE as a suitable NDT technique by which an upper limit can be set to the number of counts monitored during cycling, after the first complete cycle, which will enable the identification of low strength composites.

References

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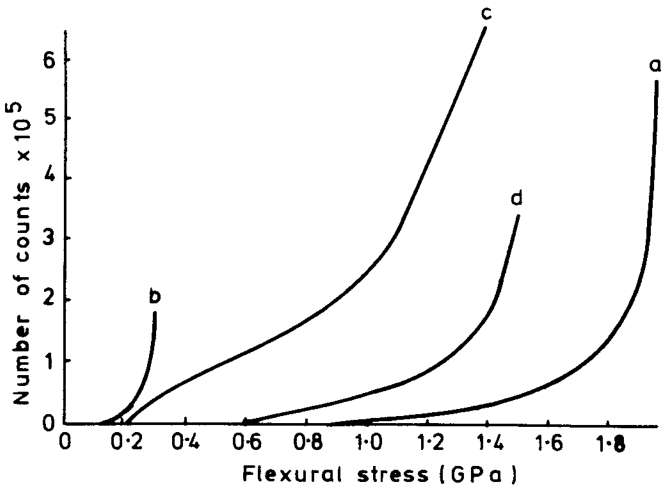

Figure 1 Acoustic emission responses of (a) green, (b) carbonised, (c) isothermal CVD and (d) thermal gradient CVD carbon-carbon composites

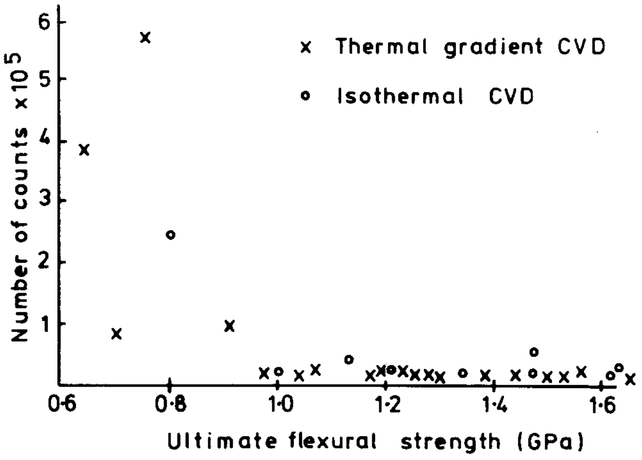

Figure 3 Relationship between the ultimate flexural strength and the acoustic emission monitored during flexural cycling between 0 and 0.4 GPa

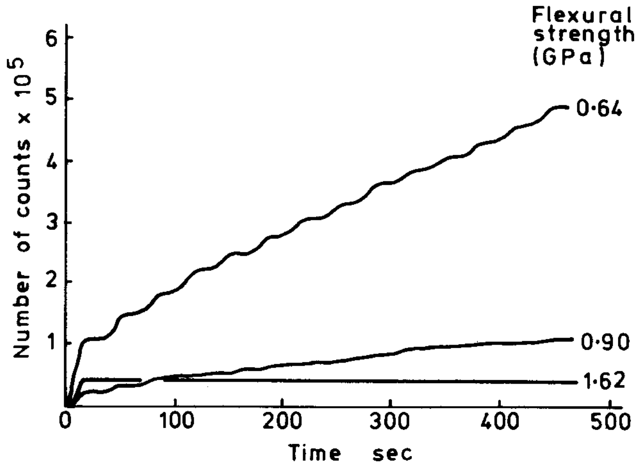

Figure 2 Acoustic emission from carbon-carbon composites during flexural cycling between 0 and 0.4 GPa